The Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities

Neeharika Naik-Dhungel
Program Manager, U.S. EPA Combined Heat and Power Partnership
Ariel Rios Building
1200 Pennsylvania Avenue, N. W.
Mail Code: 6202J
Washington, DC 20460

ABSTRACT

The U.S. Environmental Protection Agency's (EPA's) Combined Heat and Power (CHP) Partnership has encouraged the integration of CHP into wastewater treatment plant designs since 2005. In 2007, the CHP Partnership completed a market analysis titled, "Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities (WWTF)." The report's target audience was the stakeholders to developing CHP at a WWTF, such as the local facilities, municipal utilities, developers, financiers, and energy supply companies (ESCO). The report objective was to develop engineering rules of thumb, quantify market potential, and identify short-term opportunities for increasing the deployment of biogas-fueled renewable CHP at WWTFs in the United States.

The report yielded two key findings. First, in general, each 4.5 MGD [0.197 m^3/s] of influent flow at a WWTF that employs CHP can be utilized to produce approximately:

- 100 kilowatts (kW) of electricity to offset purchased electricity or sell to the grid.
- 12.5 million British thermal units (MMBtus) per day [153 kW] of thermal energy that can be used as heat for an anaerobic digester and/or for space heating loads.

Second, if all WWTFs in the U.S. with anaerobic digesters and influent flow rates greater than 5 million gallons per day (MGD) [0.219 m^3/s] installed CHP systems, approximately 340 Megawatts (MW) of clean electric capacity could be generated, offsetting 2.3 million metric tons of carbon dioxide emissions annually (these reductions are equivalent to removing the annual emissions of approximately 430,000 cars).

The report substantially advanced the Partnership's work in the wastewater treatment sector by establishing an overall technical potential estimate, and presenting a strong case for CHP at WWTFs. Since the report was first published, the Partnership has found that there is interest in investigating CHP applications at facilities between 1 and 5 MGD. There is also an interest better understanding the economic opportunities for CHP applications. In tandem, there is an interest in the challenges to successful project development including how systems can benefit from federal and state clean energy policies and incentives.

The CHP Partnership's goal is to complete a comprehensive update of the 2007 report that reflects these technical and economic drivers. The report will include real world examples of CHP installations to highlight the market drivers, benefits, barriers, and lessons learned from them. The report findings will be of interest to the various stakeholders in the CHP WWTF

industry at WWTF, local utilities and government, and project developers and intends the report to be completed by the fall of 2010.

Keywords

Combined heat and power; biogas; anaerobic digesters; clean energy; sustainability; renewable fuel, wastewater treatment facilities, WWTF, reliability, energy efficiency

Introduction

The EPA's) (CHP) Partnership is a voluntary program designed to foster cost-effective CHP projects. The goal of the Partnership is to reduce the environmental impact of power generation by building cooperative relationships with the CHP industry, state and local governments, and other stakeholders to expand the use of CHP. The Partnership provides a variety of education/outreach, technical assistance, and public recognition tools and services to those sites considering implementation of CHP projects.

The U.S. drive for clean, renewable domestic energy sources and the municipal wastewater treatment industry's need to upgrade essential infrastructure cost-effectively are converging in the area of anaerobic digester gas (ADG or biogas) fueled renewable power and heat. CHP is a reliable, cost-effective option for wastewater treatment facilities (WWTF) that have, or are planning to install, anaerobic digesters. Biogas flow from these digesters can be used in a CHP system as "free" fuel to generate reliable electricity, thermal energy, and heat for the WWTF. WWTFs are critical for maintaining public sanitation and a healthy environment, and must be able to operate in the event of a natural or man-made disaster, as well as any utility power outage.

CHP can be a valuable infrastructure addition for WWTFs because of the energy and cost savings it can provide, the environmental benefits in the process, and the reliability and security advantages it can provide by producing electricity and heat on site, independently from the grid. CHP systems provide critical power and thermal reliability for WWTFs by producing power and heat 24 hours per day, 7 days per week. CHP integrates seamlessly into existing heating and electrical systems and provides a steady supply of hot water or steam. A CHP system can also be configured to provide backup power in the event of a utility outage so operations can continue during a blackout or catastrophic event. A well-designed CHP system that is powered by digester gas offers many benefits for WWTFs because it can:

- Produce power at a cost below retail electricity.
- Displace fuels normally purchased for the facility's thermal energy needs.
- Qualify as a renewable fuel for green power programs.
- Offer an opportunity to reduce greenhouse gas and other air pollution emissions and conserve energy.
- Enhance power reliability and energy security for the treatment plant.

With CHP, improved efficiency means that your facility uses less fuel; therefore, operating and maintenance costs are reduced, while environmental performance is improved. The power and heat produced on site by the CHP system displaces purchases of electricity and fuel for boilers. The same reductions in purchased electricity that result in energy cost savings also reduce the environmental impact of WWTF operations by reducing air pollution. CHP is a reliable, cost-effective option for WWTFs that have, or are planning to install, anaerobic digesters. The biogas flow from anaerobic digesters can be used as “free” fuel to generate electricity and power in a CHP system using a turbine, microturbine, fuel cell, or reciprocating engine. The thermal energy produced by the CHP system is then typically used to meet digester heat loads and for space heating. Because of its ability to produce electricity and heat on site, independently from the grid, CHP is a valuable infrastructure addition for WWTFs.

In 2007, the CHP Partnership completed a market analysis titled, “The Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities.” The report objectives were to develop engineering rules of thumb, quantify market potential, and identify the near-term opportunities for increasing the deployment of biogas-fueled renewable CHP at WWTFs in the United States.

The CHP Partnership’s goal is to complete a comprehensive update of the 2007 report that will include the following components:

- Update the technical potential provided in the 2007 report to reflect changes in the marketplace
- Expand the technical potential to investigate CHP applications at facilities between 1 and 5 MGD
- Examine the economic potential of CHP applications taking into consideration various rate structures
- Examine project development components to elucidate installation and operational strategies and challenges, and
- Provide real world examples of CHP installations that highlight the market drivers, benefits, barriers, and lessons learned to CHP implementation at WWTFs.

The updated report, therefore, will not only provide a summary of the current technical and economic market potential for CHP at WWTFs, but also a more comprehensive perspective on issues related to CHP project development at WWTFs The Partnership intends this report to be completed by the fall of 2010.

Methodology

The 2007 report provided basic information for assessing the potential technical fit for CHP at WWTFs that have anaerobic digesters. The report provided the following information:

- The size of facilities that have the greatest potential for employing cost-effective CHP.
- Rules of thumb for estimating a CHP system’s potential electricity and thermal outputs based on wastewater flow rate.
- The emission reduction benefits associated with CHP at WWTFs.
- The cost-effectiveness of representative CHP systems at WWTFs.
- Strategic issues involved with employing CHP at WWTFs.

The primary datasets examined to assess technical potential in the 2007 report were the 2004 EPA Clean Watersheds Needs Survey (CWNS) database and the Department of Energy (DOE) Oak Ridge National Laboratory (ORNL) CHP Installation Database.

The updated report will contain four main elements: (1) discussion of the current market; (2) an estimate of technical potential; (3) estimate of economic potential; and (4) CHP development strategies and challenges.

The current market potential will be identified based on the following criteria:

- The number and capacity of WWTFs with influent flow rates greater than 1 MGD
- The number and capacity of WWTFs with and without anaerobic digestion
- The number and capacity of WWTFs with and without biogas utilization
- The number and capacity of WWTFs that currently utilize CHP

The technical potential estimate will be developed using current market data and the conclusions generated in the 2007 analysis (4.5 MGD [0.197 m^3/s] of influent flow can result in 100 kW of electricity and 12.5 MMBtus [153 kW]). The technical potential in the updated report will be based on the to-be-released 2008 EPA CWNS database and the most up to date version of the DOE ORNL CHP Installation database. The CWNS data and the CHP database will be cross referenced to further evaluate the size relation of existing CHP systems and digester capacities at WWTF. As appropriate, a discussion on why WWTF install digesters, what is driving this, and the likelihood of increased use of digesters in the future will be included. In this manner, we hope to better understand the minimum size criteria and other operating characteristics for economic CHP at WWT facilities. Recognizing the voluntary nature to both these datasets, the Partnership will consult other industry-regarded sources to verify the data as best as possible. The technical potential cost to power rates will also be reviewed and updated to reflect current market conditions.

The report will present an economic potential for CHP at WWTFs for each of the following types of facilities:

· Facilities that have anaerobic digesters but no biogas utilization
· Facilities that have anaerobic digesters and biogas utilization (but do not utilize CHP)
· Facilities that currently do not have anaerobic digesters, but could potentially install a digester not for energy generation alone but to further reduce the amount and reactivity of leftover solids.

Technical analyses will utilize data from the DOE ORNL CHP Installation Database, which will be reviewed and cross-referenced against the CWNS data to discern trends in the industry. In this manner, we hope to better understand critical technical operating characteristics, including:

- Size criteria, for maximizing technical and economic feasibility of CHP at wastewater treatment facilities;

- Key conditions and characteristics conducive to CHP installations at WWTFs at the regional and perhaps state level; and
- The potential CO2 equivalent benefits nationally.

The report will present economic analyses of CHP at WWTFs based on sales and utility rate data. Understanding energy usage specifically related to WWTFs and the types of rate schedules that encourage CHP will be explored. In addition, how CHP can help satisfy renewable portfolio standards (RPS) and contribute to reductions in peak demand from various WWTF applications will be explored.

Recognizing the challenges to CHP installation at WWTFs, EPA consequently funded the Association of State Energy Research and Technical Transfer Institutions (ASERTTI) efforts to foster a better understanding the project development challenges. The ASERTTI report gleaned the following lessons when it examined strategic CHP development at several CHP installations (ASERTTI, 2009):

- CHP projects require due diligence from design through operation and maintenance
- Additional training for operations and maintenance personnel is important for successful operation of a CHP system
- Immediate and continuing coordination with the local utility is highly recommended.
- WWTFs need to be aware of the hazards of potentially highly corrosive siloxane deposits on CHP equipment
- A rigorous gas pre-treatment approach is needed for specific applications—thorough gas analysis and possible gas scrubbing may be required

The Partnership's report update will build on this work through additional case studies, and present an analysis to discern any overall patterns observed to successful project development. The Partnership will draw on experience from Partners to develop a summary of the key drivers, benefits, barriers, and lessons learned that WWTFs considering CHP can use to help inform their decisions. In addition, the Partnership will examine facilities that had used CHP previously to determine the lack of incentives to continue with its use.

In addition to these four main sections, the updated report will contain appendices that present the key assumptions and criteria used for the technical and economic potential analyses, a full listing of WWTFs that have any technical or economic CHP potential sorted by payback period, case studies, and a list of additional resources.

The outline for the updated report is presented as Exhibit 1 at the end of this paper.

Results

The original 2007 market analysis report showed that ddepending on the WWTF, costs can range from:

- 3 cents per kilowatt-hour (kWh) to 6.5 cents/kWh for a 126 kW microturbine.
- 9.1 cents/kWh to 10.2 cents/kWh for a 300 kW fuel cell.

- 0.1 cents/kWh to 3.8 cents/kWh for a 1 MW reciprocating engine.

Although the economics of CHP at WWTFs are often attractive, in states where electricity prices are low, burning biogas directly in boilers for onsite heating needs might be more economical.

The 2010 report update is currently underway. Table 1 presents a comparison on the number of CHP systems and total installed capacity by state in December 2006, and as of January 2010. This data is current as of March 29, 2010. In December 2006, there were CHP systems at 76 sites in 24 states, representing 220 MW of capacity. As of January 2010, there were CHP systems at 116 sites in 30 states, representing 489 MW. Since December 2006, there has been an increase of 53 percent in the number of sites and an increase of 122 percent in the installed CHP capacity at WWTFs, indicating that WWTFs around the country are recognizing the benefits of CHP. Despite this impressive growth, however, there is still much potential for further development that the updated report will detail.

The original 2007 report developed engineering rules of thumb for considering CHP at WWTFs. These rules of thumb will be included in the report update and will be used in conjunction with the 2008 CWNS data to develop new technical and economic potential estimates. The rules of thumb include the following:

- A typical WWTF processes 100 gallons per day [4.38×10^{-6} m^3/s] of wastewater for every person served.
- Approximately 1.0 cubic foot (ft^3) [0.0283 m^3] of digester gas can be produced by an anaerobic digester per person per day. This volume of gas can provide approximately 2.2 W of power generation.
- The heating value of the biogas produced by anaerobic digesters is approximately 600 Btu/ft^3 [2.24×10^7 J/m^3]
- For each 4.5 MGD [0.197 m^3/s] processed by a WWTF with anaerobic digestion, the generated biogas can produce approximately 100 kW of electricity, and 12.5 MMBtus per day [153 kW] of thermal energy.

Table 1. Number of Wastewater CHP Systems and Total Capacity by State in December 2006, and January 2010

State	December 2006		January 2010	
	No. of Sites	Capacity (MW)	No. of Sites	Capacity (MW)
AK	---	---	4	3.8
AR	1	1.7	2	2.2
AZ	1	4.2	1	4.2
CA	23	38.1	35	139.1
CO	2	7.9	2	7.1
CT	1	0.2	3	1.2
FL	1	6.0	3	13.5
IA	2	3.4	2	3.4
ID	2	0.5	2	0.5
IL	2	4.3	6	11.8
IN	---	---	1	0.1
MA	1	76.0	1	76.0
MD	---	---	1	3.0
MN	2	5.1	4	7.2
MT	3	1.1	3	1.1
NE	3	5.4	3	5.4
NH	1	0.4	1	0.4
NJ	3	4.6	4	24.6
NY	5	13.3	7	14.1
OH	1	0.1	2	6.3
OR	10	5.9	10	6.4
PA	3	22.4	3	22.4
SC	---	---	1	70.0
TX	---	---	1	10.6
UT	2	2.6	2	2.6
VA	1	3.0	1	3.0
VT	---	---	1	0.1
WA	3	13.6	4	13.9
WI	2	0.5	5	35.5
WY	1	0.03	1	0.03
TOTAL	**76**	**220.1**	**116**	**489.2**

Source: DOE ORNL CHP Installation Database

Utilizing the 2004 CWNS, the original 2007 report found that more than 16,000 municipal WWTFs operated in the United States, ranging in capacity from several hundred MGD to less than 1 MGD [0.0438 m^3/s]. Roughly 1,000 of these facilities operated with a total influent flow rate greater than 5 MGD [0.219 m^3/s], but only 544 of these facilities employed anaerobic digestion to process the wastewater. Moreover, only 106 WWTFs utilized the biogas produced by their anaerobic digesters to generate electricity and/or thermal energy. The Partnership estimated that if all 544 WWTFs in the United States that operate anaerobic digesters and have influent flow rates greater than 5 MGD [0.219 m^3/s] were to install CHP, approximately 340 MW of clean electricity could be generated, offsetting 2.3 million metric tons of carbon dioxide emissions annually. These reductions are equivalent to removing the annual emissions of approximately 430,000 cars.

Undoubtedly, some of this potential has been realized since the original 2007 report; the updated report will present a new estimate of both technical and economic potential based on current market conditions.

Acknowledgements

The U.S. EPA CHP Partnership would like to acknowledge the following organizations that have contributed and will continue to contribute to the Partnerships' efforts in the wastewater treatment sector: U.S. EPA Office of Water; U.S. Department of Energy; Water Environment Federation; The National Association of Clean Water Agencies; Eastern Research Group, Inc.; Resource Dynamics Corporation; and ICF International. The Partnership would also like to thank Bob Forbes and Thomas Hahn at CH2M HILL for reviewing this manuscript and providing comments.

References

Association of State Energy Research and Technical Transfer Institutions (2009). ***Strategic CHP Deployment Assistance for Wastewater Treatment Facilities***. Available at: http://www.asertti.org/wastewater/index.html.

U.S. Environmental Protection Agency Combined Heat and Power Partnership (2007). ***Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities***. Available at: http://www.epa.gov/chp/documents/wwtf_opportunities.pdf.

U.S. Environmental Protection Agency (2008), ***Clean Watershed Needs Survey (CWNS) 2004 Report to Congress***. Available at: http://www.epa.gov/cwns/2004rtc/cwns2004rtc.pdf.

Exhibit 1 - Proposed Draft Outline to 2010 Report Update

I. Executive Summary

II. Introduction

III. The Market
   1. Number and capacity of WWTFs greater than 1 MGD
   2. Number and capacity of WWTFs with anaerobic digestion
   3. Number and capacity of WWTFs without anaerobic digestion
   4. Number and capacity of WWTFs with anaerobic digestion and biogas utilization
   5. Number and capacity of WWTFs with anaerobic digestion and no biogas utilization
   6. Number and capacity of existing WWTFs with CHP

IV. Technical and Economic Potential Estimate for CHP at WWTFs
   1. Data Sources and Methodology
      i. Data Sources
         1. 2008 CWNS
         2. DOE CHP Installation Database
         3. EIA utility price data and individual utility tariff data
         4. Data from other stakeholders
      ii. Methodology
         1. Technical potential
         2. Economic potential
   2. Technical Potential
      i. 2007 Analysis Basis
      ii. National electric generation potential from CHP at WWTFs
         1. CHP at WWTFs that have anaerobic digesters but no biogas utilization
         2. CHP at WWTFs that have anaerobic digesters and biogas utilization (but don't utilize CHP)
         3. CHP at WWTFs that do not have anaerobic digesters (assuming they install digesters for reasons other than energy generation e.g.., odor control, solids reduction, restrictions on land application programs, etc.
      iii. Potential CO_2 emission benefits
   3. CHP Technologies for WWT
      i. Examples of existing CHP systems in use at WWT facilities
      ii. Key cost and performance characteristics of applicable CHP systems
      iii. Critical operational issues for CHP systems at WWT facilities
      iv. Applicable incentives and revenue streams
   4. Economic Potential
      i. Number of WWTFs and total generation (based on 4.5 MGD=100 kW) that have paybacks (of any timeframe) – Specifically quantify and aggregate those WWTFs with paybacks of 5-7 years or less
         1. CHP at WWTFs that have anaerobic digesters but no biogas utilization
         2. CHP at WWTFs that have anaerobic digesters and biogas utilization (but don't utilize CHP)
         3. CHP at WWTFs that do not have anaerobic digesters (assuming they install digesters for reasons other than energy generation, e.g., odor control, solids reduction, restrictions on land application programs, etc.
      ii. Key cost information of representative CHP systems

iii. Potential CO_2 emission benefits

V. Market Development Strategies and Challenges

1. Market Drivers
   i. State/local/facility energy/sustainability plans
   ii. High electric rates
   iii. Odor control
   iv. Reduction of solids
   v. Federal/state/local policies and incentives (e.g., RPS, state incentives, etc.)
   vi. Enhanced reliability for critical infrastructure
2. Benefits
   i. Produces power at a cost below retail electricity
   ii. Displaces fuels normally purchased for the facility's thermal needs
   iii. Qualifies as a renewable fuel for green power programs
   iv. Offers an opportunity to reduce greenhouse gas and other air pollution emissions
   v. Enhances power reliability for the treatment plant
3. Challenges and Barriers
   i. Lack of facility understanding of CHP systems
   ii. New capital expenditures for anaerobic digesters and/or CHP equipment
   iii. Lack of adequate fuel source (especially for smaller plants)
   iv. Gas pretreatment strategies
   v. Gas cleanup costs
   vi. Additional training specific to handling CHP system process
   vii. Utility issues (e.g., interconnection, standby rates, degree of communication)
4. Lessons Learned
   i. Provide lessons learned based on the industry survey on benefits, challenges and barriers. The industry survey will be based on Partner experience, the ASERTTI report, and independent research.

VI. Appendix A: Key Assumptions and Criteria Used for Technical and Economic Potential Analyses

VII. Appendix B: CHP Potential by Facility (based on 4.5 MGD = 100 kW)

1. List of WWTFs in U.S. (greater than 1 MGD) that have any technical or economic potential, sorted by payback period (sorted from lowest to highest, with those with only technical potential listed as payback "NA"). Organized by:
   i. WWTFs that have anaerobic digesters but no biogas utilization
   ii. WWTFs that have anaerobic digesters and biogas utilization (but don't utilize CHP)
   iii. WWTFs that do not have anaerobic digesters (assuming they install digesters for reasons other than energy generation)

VIII. Appendix C: Database of wastewater treatment plants considered in the report analysis

IX. Appendix D: Additional Reference Resources

1. EPA CHP Partnership Resources
2. Other Organizations